The WRP Notebook

CONTENTS

WRP Technical Note VN-CP-4.1
May 1992

Measuring Periphyton Growth in a Bottomland Hardwood (BLH) Wetland

PURPOSE: This technical note introduces a method to measure periphyton growth in BLH wetland forests during the flooded winter and spring season using a device specifically designed to account for water fluctuation and high turbidity.

BACKGROUND: As primary producers, periphyton (attached algae) are an important component of many aquatic ecosystems. They create complex and diverse habitats used by many invertebrates and small fish for protection and food.

During the summer, the forest floor of a BLH wetland is dry and shaded by the dense canopy of woody vegetation. As a result, algal productivity in BLH forests appears insignificant during this time of year. However, the character of the BLH forest is transformed during the wet season. Trees and shrubs are bare, opening the canopy for direct light penetration to the forest floor. This season is dominated by periodic flooding with water depths fluctuating unpredictably and at varying rates. The water flowing through the system is often high in nutrients. Dense periphyton growths have been observed attached to floating debris in the BLH forest during winter and spring floods, suggesting that the role of periphyton during the wet season should be examined.

Even under these favorable conditions, the water of BLH systems is often turbid, limiting light penetration into the water column and restricting the depth at which periphyton can grow. Although the dormant BLH forest provides ample substrate for periphyton attachment, flood cycles usually occur at intervals greater than periphyton colonization and growth rates (i.e., the periphyton are either left exposed to desiccation by low flood cycles or flooded to depths where light becomes limiting.) Because of this, periphyton rarely attach to standing vegetation, but are instead attached to twigs, branches and trees which float with the flood cycles, thus providing well lit substrate near the surface of the water.

METHODS: The need to quantify periphyton growth potential on floating debris in BLH forests led to the development and construction of a simple plexiglass device especially suited for that purpose (Figure 1). The device consists of a sealed cylindrical float 15 cm in diameter and 75 cm long. Attached at one end, perpendicular to the main axis of the float, is a short 5-cm-diam cylinder. A pipe passes through the short cylinder and presses vertically into the sediment. This allows the float to swivel with changing currents and to rise and fall with floods, keeping the attached organisms at a uniform water depth. Artificial substrates for experimental growth of periphyton consist of strips of plexiglass (60 by 2.5 by 0.32 cm). The strips are prescored at 7.5-cm intervals throughout the length so that the 7.5-cm sections can be snapped off as uniform samples. Using this configuration, the smallest sample has a surface area of 37.5 cm^2 when both sides are used. The water column can be monitored at 7.5-cm intervals from the surface to a depth of 60 cm. Thirty strips can be suspended from each float. This configuration allows for flexibility in sampling design, e.g., replication and vertical resolution. During a study, the entire device is installed in a natural local depression after floodwaters provide enough depth to freely float the device. Installation in a depression maximizes water depth to keep the strips of artificial substrate from contacting the sediment between flood peaks. The biological sample scraped

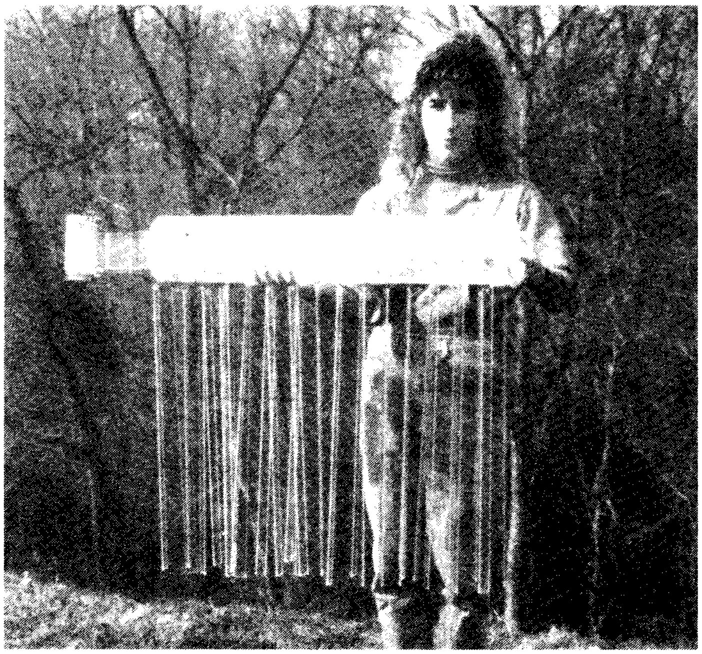

Figure 1. Photograph of the device developed to measure periphyton growth in BLH forests

from the plexiglass sections can be analyzed in many ways. Common techniques include pigment analysis and gravimetric measurement of biomass.

RESULTS: This device was used in a BLH study on the Cache River in Arkansas. Chlorophyll *a* was used as a measure of periphyton biomass. Maximum biomass was observed at the surface and decreased rapidly to very low values at a depth of only 0.5 m (Figure 2). This biomass was achieved after 9 weeks of growth. Six species of chironimid larvae inhabited the periphyton growing at the artificial substrate.

CONCLUSION: The device described herein can be used to quantify potential community production and to help elucidate the importance of this production to the function of BLH forests. The device can be constructed easily and inexpensively.

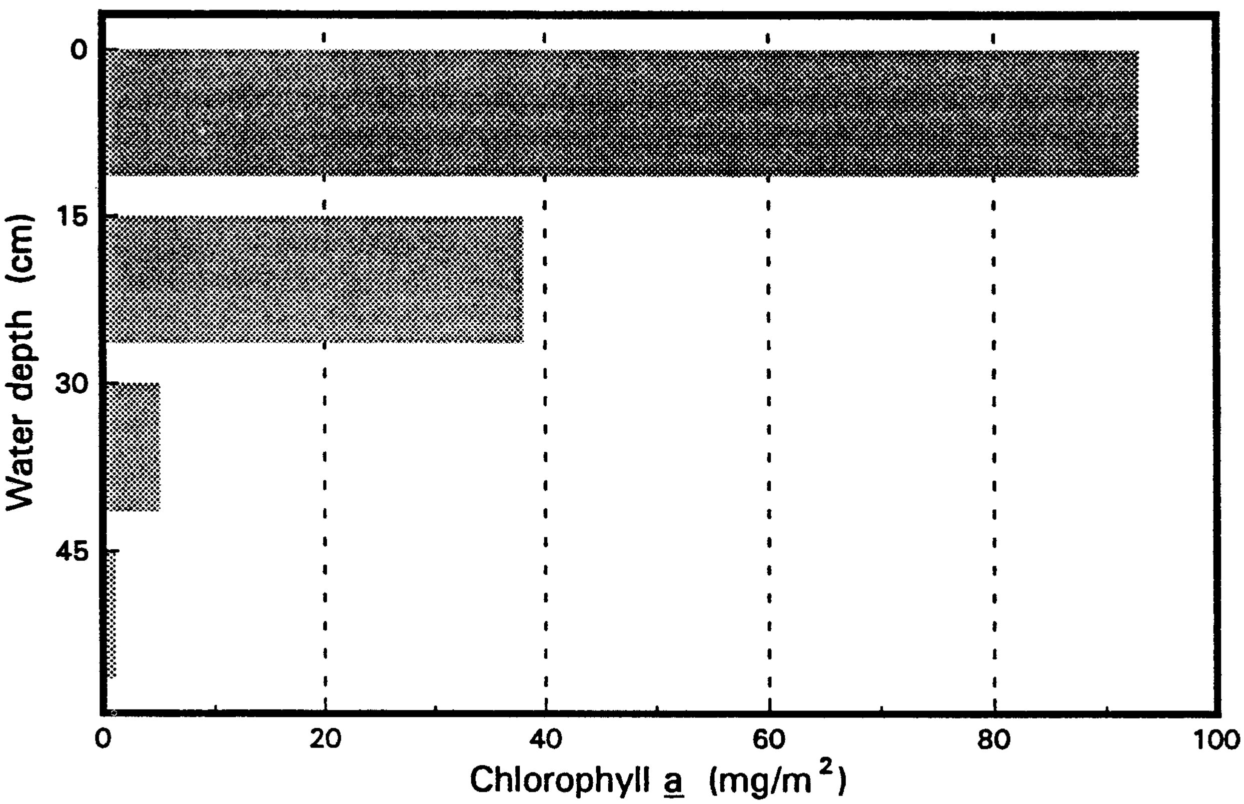

Figure 2. Graph illustrates the high biomass of periphyton present near the surface of the water and the rapid decrease with water depth

Results of field investigations using the device have shown that there is great potential for periphyton growth on floating debris in BLH forests during the flooded season of winter and early spring when most of the other primary producers in the system are dormant. Observations of invertebrates inhabiting the periphyton growths indicate that the periphyton may be an important food source and may provide habitat in the BLH during the flooded season.

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WRP Technical Note VN-DL-1.1
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Physiological Response to Flooding for Wetland Indicator Plants

PURPOSE: This Technical Note describes a general method that may help refine the indicator categories of some problematic wetland plant species within different geographic regions.

BACKGROUND: The U.S. Department of the Interior, Fish and Wildlife Service, publishes regional lists of plant species that occur in wetlands. These lists are compiled from literature, field data, comments received from biologists within each region, and the experience of regional review panel members. Each species within a region that occurs in wetlands is assigned a wetland indicator status based upon its frequency of occurrence in wetlands. Table 1 shows the estimated probability of occurrence for indicator categories for wetland plant species.

Wetland plant species with little field data or with broad ecological amplitude are difficult for regional review panels to categorize accurately, and are therefore problematic. Regional problematic species, when repeatedly part of the hydrophytic vegetation determination, can leave the delineator uncertain about the wetland determination. There is a need to develop method(s) to refine indicator status of problematic species.

Species that have a higher probability of occurrence in wetlands likely exhibit a higher tolerance of wetland conditions, i.e., water saturated, chemically reduced soils. Differential physiological responses to flooding may provide a potential method to refine the indicator status of some problematic wetland plant species. The method presented in this technical note uses photosynthetic response to inundation by wetland plant species that have been identified as having reliable indicator status as a baseline for comparison.

METHODS: Species with dependable indicator status were selected by biologists who routinely perform wetland delineations within the geographic area of the U.S. Army Engineer District, Buffalo, NY. Plant species studied were *Typha latifolia* (Cattail), *Scirpus cyperinus* (Wool-grass), *Parthenocissus quinquefolia* (Virginia Creeper), and *Solidago nemoralis* (Gray Goldenrod). The indicator status assigned to these species by Reed (1988) is: Cattail (OBL), Wool-grass (FACW+), Virginia Creeper (FACU), and Gray Goldenrod (UPL). Live specimens of each species were collected, vegetatively propagated, and grown in the greenhouse. Plants were inundated in fiberglass tanks to 5 cm above the top of the pots. Most of the leaves were above the water. Photosynthesis and other gas exchange parameters were measured before inundation, and weekly after inundation. Control plants were not inundated. Measurements were made in the greenhouse under constant light intensity. Three replicate plants were measured for each of the control and inundated treatments.

RESULTS: Photosynthetic response of the plant species to inundation is presented in Figure 1. Day zero represents pre-inundation measurements. The OBL, FACW+ and FACU species showed an initial decline in photosynthetic rate associated with inundation (Fig. 1). Photosynthesis of both the OBL and FACW+ species recovered after seven days of inundation, while that of the FACU species continued to decline. Inundated FACU plants were dead after 30 days. Photosynthesis of the inundated OBL species recovered after two weeks and exceeded that of the non-flooded control plants.

Table 1. Probability of occurrence in wetlands and uplands of species with different wetland indicator status

Indicator status	% of frequency of occurrence in:	
	Wetlands	Uplands
OBL*	>99	<1
FACW	67-99	1-33
FAC	34-66	34-66
FACU	1-33	67-99
UPL	<1	>99

* In addition, the FACW, FAC, and FACU categories may be modified with '+' or '-' to indicate the higher or lower part, respectively, of the range of occurrence in wetlands for that category.

Although photosynthesis of the inundated FACW+ species also recovered after two weeks, it did not exceed that of the control. The response of the UPL species was difficult to characterize because of scatter in the data. The general decline in photosynthesis observed in control plants of all species may represent a response to elevated daytime greenhouse temperatures.

CONCLUSION: The responses of the OBL, FACW+ and FACU species were distinct, perhaps reflecting different levels of flooding tolerance. This preliminary study suggests that photosynthetic response to inundation may be helpful in refining the indicator status of some problematic wetland plant species. Additional species of each indicator status must be studied to verify and refine the trends observed here. A larger set of reliable baseline species of all indicator classes should be characterized. Then several problematic species should be tested and their responses compared to those of the baseline species.

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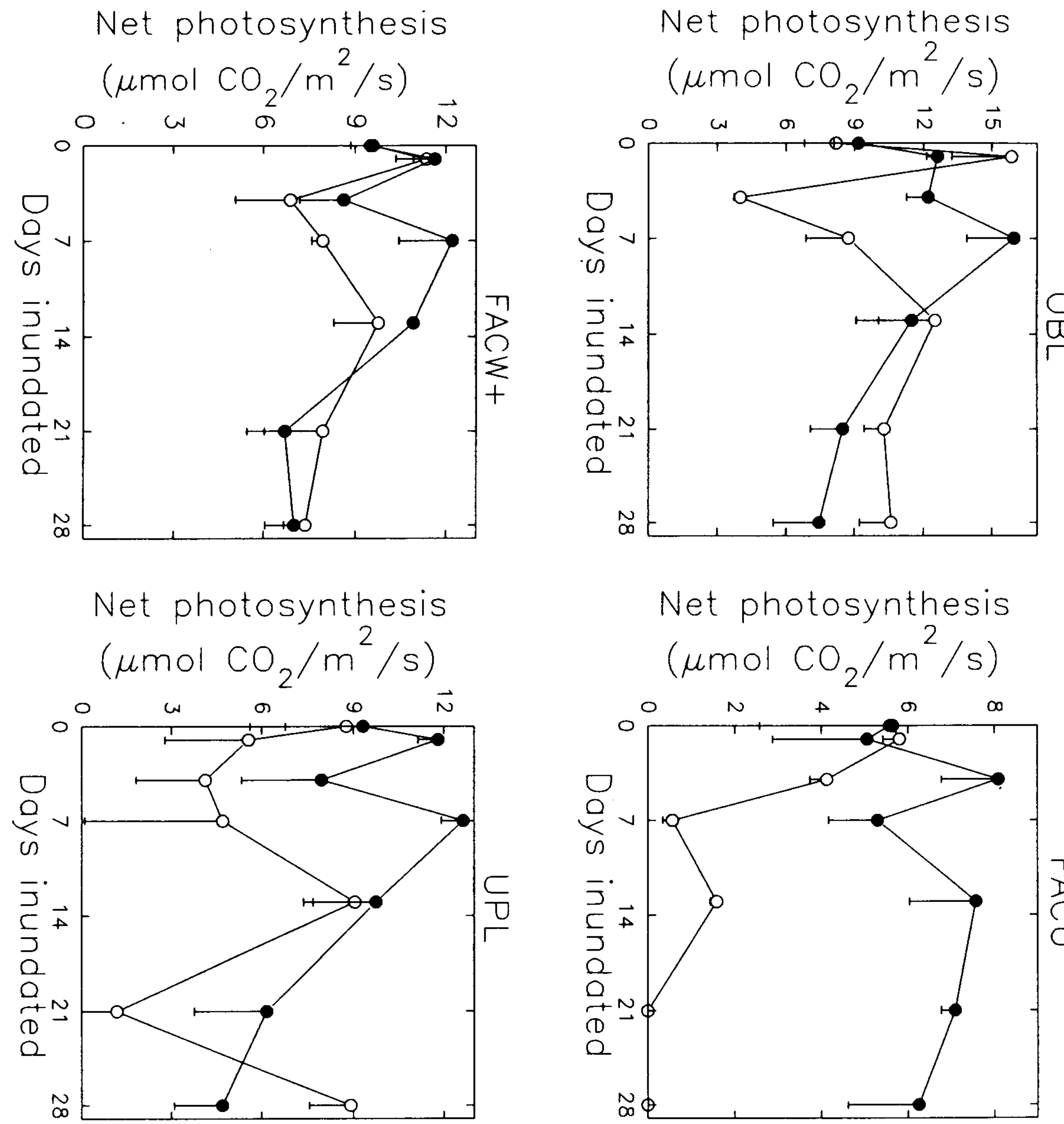

Figure 1. Net photosynthesis for four plant species exposed to inundation. OBL = *Typha latifolia*, FACW + = *Scirpus cyperinus*, FACU = *Parthenocissus quinquefolia*, and UPL = *Solidago nemoralis*. Open circles represent inundated plants, closed circles represent noninundated plants. Each circle represents the mean of three replicates. Vertical bars are standard deviations of the mean.

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Container Oak Seedlings for Bottomland Hardwood (BLH) Restoration

PURPOSE: This technical note discusses growing Nuttall oak (*Quercus nuttallii* Palmer) seedlings in containers for small (BLH) restoration projects. This method may increase seedling survival and improve restoration success in frequently flooded areas.

BACKGROUND: Restoration of BLH forests often requires reforestation of reclaimed agricultural fields subject to frequent flooding. Establishing oak species (*Quercus* spp.) in these areas will improve the habitat function of BLH by providing mast for wildlife. For many areas, the conventional planting season of mid-December to late-February coincides with periods of heavy precipitation and flooding. While some oak species are considered moderately flood tolerant, they cannot withstand long periods of inundation, especially when flooding extends into the growing season.

Traditionally, restoration has been accomplished with bare-root seedlings or direct seeding with acorns. Several problems arise when flooding occurs during the planting season: 1) inaccessibility of the site, 2) inundation of newly planted seedlings, and 3) poor stock quality as a result of unavoidable, long-term storage (i.e., mold, mildew, and dry rot). Storage is often unavoidable because nursery operators must harvest seedlings before preparation of the seed bed for next year's crop. If planting occurs prior to flooding, seedlings must tolerate flooding during the growing season and survive the summer drought that usually follows. A stock which can be planted after the spring flood, yet survive the anticipated summer drought, is needed for successful reforestation of frequently flooded areas.

Container oak seedlings may alleviate planting problems encountered with bare-root seedlings and direct-seeding on flooded sites. For instance, growth in containers promotes a more fibrous root system as well as a higher root to shoot ratio (Fig. 1). This is a goal pursued by nursery operators with bare-root stock. However, harvesting bare-root seedlings results in a large portion of the root system remaining in the seed bed. During planting, pruning of the root system is often necessary to properly plant the seedling. Consequently, the root system of a planted bare-root seedling consists of only a few primary and secondary roots. In contrast, the root system of a container seedling is bound to the media until planting, resulting in no root damage or loss from harvesting or pruning. This allows the planting of an undisturbed fibrous root system with a large surface area, increasing absorption capacity for water and nutrients in drought conditions and oxygen in hypoxic conditions.

The literature supports the use of container seedlings to extend the planting season (Graber 1978, Yeiser and Paschke 1987). Extending the planting season allows flexibility in the planting schedule and eliminates storage problems encountered with bare-root seedlings and seed. Seedlings remain in the containers and receive water and nutrients until optimum planting conditions occur.

METHODS: Choose a species that is suitable to the conditions of the site. Nuttall oak, a species known to grow well on poorly drained soils, is a good example. The seed source should be located within a 100 mile radius of your planting area. Nuttall oak seeds can be collected beginning in October or purchased from a seed vendor. Seed may be stored according to methods prescribed by

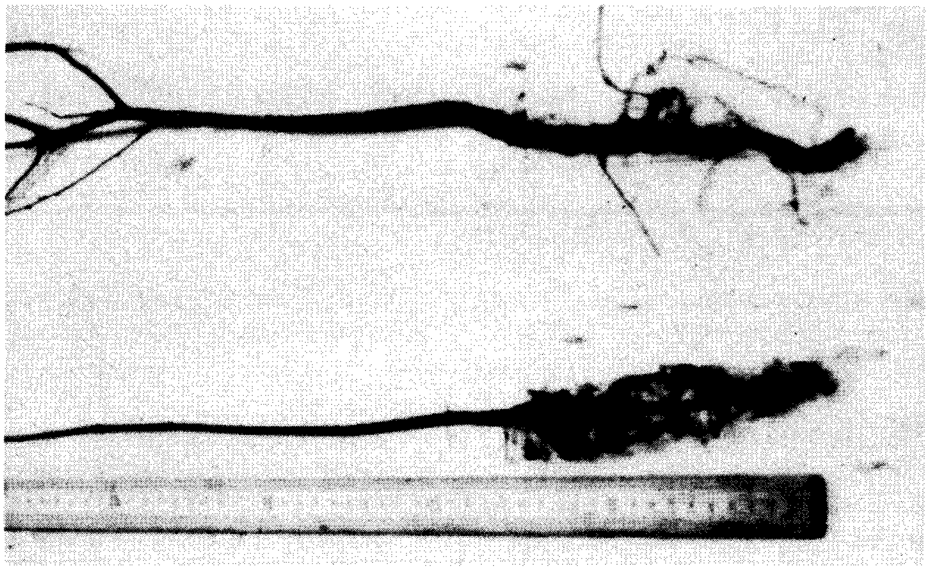

Figure 1. Comparison of root system of bare-root and container seedlings

U.S. Department of Agriculture Forest Service (1974). The seeds should be soaked in water for a 24 hr period. Floating seeds should be discarded because they are probably not viable. The non-floating seeds are placed into polyethylene bags for a period of 60 to 90 days at 5°C. This process is known as artificial stratification, necessary to break seed dormancy. Following the stratification period, seeds should be sown directly into containers filled with potting medium. Suggested container size is 164 cm^3 plastic cone containers filled with a 1:1 ratio of vermiculite and sphagnum moss. Place the containers at a 8 x 8 cm spacing. This spacing promotes the development of a uniform crop of seedlings by reducing inter-seedling competition for light and allowing homogeneous delivery of water and nutrients. Germination and initial growth (approximately 3 weeks) should take place in a greenhouse. Seedlings should then be moved to a shade house covered by 50% shade cloth for the remainder of the growing season (Fig. 2).

Seedlings should be checked daily for desiccation by touching the media and observing any evidence of leaf wilting to determine when watering is necessary. As temperature increases, it may be necessary to increase watering to daily either in the morning or late evening. The potting medium does not supply nutrients to the growing seedlings, it is therefore necessary to fertilize. Fertilizer should be applied weekly, beginning with a 9-45-15 (N-P_2O_5-K_2O) to promote root growth. After a 3 week period, fertilize with 20-20-20 or 15-30-15 to maintain shoot and root growth. Toward the end of the growing season, fertilizer should be switched back to 9-45-15 and watering reduced to promote bud set. Magnesium in the form of epsom salt ($MgSO_4$) and liquid iron can be added to the fertilizer solution to supply minor nutrients. The actual amounts of fertilizer applied will depend on the amounts of watering and rainfall. For the 1992 growing season at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, each seedling received approximately 67 mg of nitrogen.

CONCLUSION: Some concerns to be noted when growing container seedlings are maintaining moisture within containers and the leaching of fertilizer. Maintaining moisture in the containers can be a problem during summer months because of high evapo-transpiration rates. This can be avoided with an automated irrigation system. Leaching of fertilizer may occur due to increased watering. In addition to fertilizer rates mentioned above, slow-releasing fertilizer (13-13-13) pellets can be added as top dressing at a rate of 500 mg/container to compensate for the leaching.

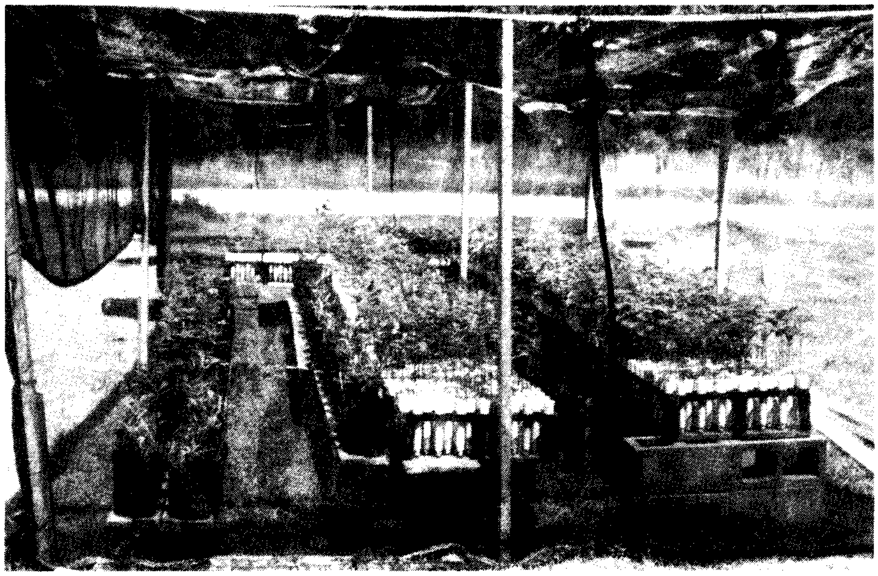

Figure 2. Container seedlings in shadehouse covered by 50% shade cloth

Production of a uniform crop of container seedlings can be achieved (Table 1). For all of the measured variables, bare-root seedlings averaged larger than the container seedlings. However, the key component to seedling survival is the establishment of a viable root system. The container seedlings, because of a fibrous network of roots, have a greater capacity for absorption (Fig. 1) which translates into a better chance of seedling establishment in difficult situations. Although the root systems of bare-root seedlings appear to be more than twice the size of container seedlings, the mass consists of only primary and secondary roots which are often pruned before planting.

Previously, container seedlings have not been frequently used in the South due to high cost and unavailability of large quantities. Availability is no longer a problem but many still consider the initial cost too high. However on a per seedling basis, purchase price is about $ 0.25 for a bare-root seedling versus $ 0.29 for a container seedling. The difference in seedling cost is balanced with the potential for increased survival. Preliminary data from a field study at Lake George, MS, show 75% seedling survival for container stock versus 45% for bare root. The selection of a tree species suitable for the site, and seedlings grown in containers, coupled with an extended planting season, may allow the reforestation of frequently flooded sites which otherwise would be difficult or impossible to replant.

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Table 1. Morphological Characteristics of Container and 1-0[1] Bare-root Nuttall Oak Seedlings Outplanted at Lake George, MS, Jan. 21,1993

	Stocktype			
	1-0 Bareroot		Container	
Variable	Mean	Standard Error	Mean	Standard Error
Height (cm)	62.9	2.0	47.1	1.7
Root Collar Diameter (mm)	7.4	0.3	6.1	0.1
Root Oven Dry Weight (g)	6.8	0.5	2.5	0.1
Shoot Oven Dry Weight(g)	8.9	0.7	3.1	0.1
Shoot to Root Ratio	1.3		1.2	

[1] 1-0 Bare-root describes a seedling grown one year in a seed bed and no years in a transplant bed.

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Selection and Acquisition of Wetland Plant Species for Wetland Management Projects

PURPOSE: Wetland management projects often require the establishment of wetland plants under site conditions that affect plant establishment, growth, and reproduction. Wetland plant species selection is dictated by site-specific hydrology, soils, and energy from wind, waves, and currents. The purpose of this technical note is to discuss considerations for selection of plant species that will successfully tolerate wetland site conditions and meet the project goals.

PROJECT GOALS: The project goal is a primary factor to be considered when selecting plant species for a wetland management project. Goals affecting the species selection process include:

- Prevention of wind/water erosion.
- Flood storage/conveyance.
- Aquatic and wildlife habitat.
- Water quality enhancement.
- Aesthetic/heritage value.

Few plant species would be the optimal choice to accomplish all these goals. For example, plants differ in their ability to stabilize sediments. Unlike annuals, perennial species, such as trees and shrubs, generally have root systems that provide year-round protection against sediment erosion. Nutrient removal from inflow into a wetland may be increased in some cases by periodically harvesting the wetland plants that assimilate nutrients. In these cases, trees would be less desirable than herbaceous species.

Although project goals may not address the need for plant species diversity, maximum species diversity is desired, for several reasons. Generally, wildlife diversity and usage increase with increased plant species diversity. More importantly, however, is the improved potential for project success. It is not possible to determine prior to project construction whether a plant species will be able to tolerate the managed site conditions. Uncontrollable factors, such as weather and infestations, can stress newly planted vegetation. If several species are planted on a project site, it is likely that at least some of them will survive under the unpredictable conditions experienced through time. In addition, a diversity of species will be more likely to resist invasive species and herbivores, as well as recover from disturbances.

SITE-SPECIFIC CONDITIONS: A critical step in plant species selection is to define the range of environmental conditions that characterize the project site conditions. Basic problems encountered in the establishment of marsh and aquatic plants are unfavorable water depths and fluctuations, nutrient deficiencies, excessive turbidity, excessive wind or current action, unsuitable substrates, and polluted sediments. Knowledge of the site history and landscape setting may indicate the presence of limiting factors that may not be visible. Most importantly, however, the hydrological conditions must be defined because these are the primary factors that limit wetland plant distributions.

These problems should be dealt with as the project plan is being developed, to the greatest possible extent. Plants will tolerate and, in part, ameliorate poor site conditions; however, too much stress on the plants will cause the project to fail.

ENVIRONMENTAL TOLERANCES: Plants are morphologically and physiologically limited with regard to where they are able to grow. The plant growth form (e.g., height, rooting depth, stem strength against breakage) largely determines whether or not the plant can, for example, withstand current and wave action, extend leaves above water level to avoid complete submergence, or spread into open areas by extending rhizomes. Physiological limitations of wetland plants are often related to attaining adequate light and oxygen to maintain a viable energy balance while submerged.

Water level management is key to determining the success of a wetland vegetation project. In fact, the zonation of plant species commonly observed in marshes and floodplains is primarily controlled by depth and duration of inundation. Turbidity, dissolved oxygen, pH, dissolved nutrients, and other water quality parameters are secondary controls on plant distribution, with salinity acting as an important control in coastal systems.

Tolerances to key environmental conditions have been determined for many wetland species. This information is available from commercial suppliers, the local USDA Soil Conservation Service, and several published sources (e.g., Kadlec and Wentz 1974, Environmental Laboratory 1978, Allen and Klimas 1986).

NATIVE SPECIES: Selection of appropriate plant species can be aided by observing vegetation in local wetlands similar to the designed wetland (reference wetland). These plant assemblages have developed under the prevailing environmental conditions and are adapted to them. Use of native species in conditions similar to where they naturally grow helps to ensure not only good survival and growth rates, but that the plants will likely be able to reproduce and maintain themselves.

Project conditions may exist, however, for which no comparable natural wetlands exist. In these cases, it is recommended that native wetland plant species be used that have wide environmental tolerance ranges and are likely to tolerate project conditions. It may be necessary to ameliorate site conditions by management techniques, such as repeated application of fertilizer or control of invasive species, to maintain native species. Bioengineering techniques may be used to extend the natural range of plant species into high-energy areas.

Information on the growth and propagation of native wetland species in an area can be scarce. However, detailed listings of many wetland plants and the best propagule type for each can be found in articles by Hunt et al. (1978) and Environmental Laboratory (1978). Local USDA Soil Conservation Service plant specialists may have additional information on specific wetland plants in your area.

WETLAND PLANT ECOTYPES: It is necessary that the person obtaining plants for a wetlands vegetation management project be familiar with the concept of ecotypes. Studies of plant species with wide geographical ranges (altitudinal, latitudinal, climatic) have often shown reduced survival and growth rates of individual plants transplanted to environmental conditions different from those in which they originally grew (e.g., heat, cold, drought, soils, infestations, and flood tolerance). Even plants of the same species can die when inundated if they were grown from seeds collected in upland areas. Plants should be grown under or collected from conditions as similar as possible to the areas in which they will be planted.

Plants should be obtained from local sources. They should be transferred from areas within 100 miles latitude, 200 miles longitude, and 1,000 feet in elevation (Environmental Laboratory 1978, Gray and Leiser 1989, Pierce 1992). Growing concern is being expressed by ecologists, however, about unknown consequences of relocating genetic stock to new areas. For example, plants apparently become adapted to local pathogens, as well as beneficial mutualistic species, and their survival and growth are diminished when transplanted to different areas. The state of Florida has addressed this problem by specifying an even more limited collection area, that is, within a 50-mile radius, for plants used in wetland mitigation projects.

More detailed information on species range and growth habits is available in reports by Hunt et al. (1978) and Environmental Laboratory (1978).

SPECIES ACQUISITION AND AVAILABILITY: Additional factors that must be considered in the choice of wetland plant species include the following:

- Decisions about what species or seed source will be used.
- Nature of the chosen plant propagule.
- Date of planting.
- Number of plants required.
- Location where plants can be obtained.
- Method of transporting plants.
- Requirements and availability of storage facilities.
- Method of supervision required during planting.

The availability of an ample supply of the target species should be determined early in the planning stages of the project. Plants can be collected from areas in the region, maintained as stock in your greenhouse, or purchased from commercial suppliers. Each method of procurement has advantages and disadvantages. Lists of commercial suppliers are included in the following: Environmental Laboratory (1978), Hunt et al. (1978), Allen and Klimas (1986), Environmental Laboratory (1992).

Collecting the target species eliminates the cost of purchasing or growing propagules, while providing the most ecologically adapted plants for the area. It should be noted, however, that collecting native plants from natural areas is not always desirable. Plant collection may deplete natural populations to the point that they are lost. Activities associated with collection may alter and harm the donor site. Most importantly, digging plants from existing wetlands may be a Section 404 violation. Regulatory assistance should be sought prior to digging in wetlands.

If collecting wetland plants from existing wetlands is found to be ecologically and legally acceptable, several points should be considered. Collection and logistics costs must be evaluated as they can be prohibitively high. Collection eliminates the need for storage and expertise in the growth and propagation of the target plants. Some expertise is required, however, to accurately identify the plants of choice and to ascertain the ecotypes that may be present. Care must be taken to avoid the inclusion of weedy species that grow with target plants and to leave the donor site as undisturbed as possible.

If space and labor are available, growing your own plants can lower the cost to the project considerably while providing the desired quantities of a number of species. Although the seed germination requirements of most wetland plants are not known, some degree of stratification is normally required when using seeds. Information about seed germination requirements is available from the USDA Soil Conservation Service. Plant propagules must either be collected from wild sources or obtained from a commercial supplier.

There are some concerns to be dealt with when growing your own plants. In a greenhouse setting, problems with fertilization, watering, and control of pests must be considered. Other disadvantages would include the necessity for devoting large amounts of greenhouse space to the growing stock, the need for personnel with expertise in growing plants, and the difficulty in breaking the winter dormancy requirements of these plants. Some hardening is usually required for greenhouse-grown plants before exposing them to harsher site conditions.

The decision to purchase the target plants entails certain precautionary steps. The ability of the supplier to make the scheduled deliveries within the time frame of the project is very important to the success of the endeavor. Include some flexibility when negotiating plant delivery to allow for unexpected delays. Allow time for the supplier to grow the target plants when planning your project, since many wetland plants are grown in large quantities only as the need arises.

Plant propagules should be guaranteed to be in optimum condition (healthy and of sufficient size) by the supplier, with the option of replacing any found to be unsatisfactory. It is a good practice to have the guarantee written in the contract and to have payment dependent on this fact. It is very important to ascertain what kinds of propagules are available, as this will dictate your planting methods and labor requirements.

In spite of taking the necessary precautions, plants can arrive in poor condition. Requesting samples of the desired propagule in advance will allow you to examine the plant and verify the accuracy of identification by the supplier. Plants obtained through a supplier will not be acclimatized to the planting site, and some additional time for this can be included in your project plan. By comparison shopping and reviewing previous experiences (of yourself and others) you can ascertain the dependability of the supplier prior to the planting deadline (Pierce 1992).

CONCLUSIONS: Selection and acquisition of wetland plants for a project includes a series of steps, which begins with the development of the project goals. Acquiring the plants and ensuring delivery to the site on schedule requires planning well in advance of the planting date. Proper attention to matching native species with site conditions is the key to successful plant establishment and growth.

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WRP Technical Note VN-EM-3.1
May 1992

Design and Construction Requirements for Establishing Herbaceous Wetland Vegetation

PURPOSE: This technical note addresses some considerations and techniques for restoring or establishing herbaceous wetland vegetation. It also provides references for a more in-depth discussion of these considerations and techniques.

BACKGROUND: According to various investigators, scientists are only beginning to understand the process of wetland plant adaptation to the environment. In addition, and more importantly, scientists are investigating the effects of wetland plants on the environment.

FACTORS AFFECTING HERBACEOUS WETLAND ESTABLISHMENT: It is difficult to summarize wetland establishment and restoration in general terms and within a short technical note because so much is dependent upon the life requisites of individual plants, groups of plants, and the organisms that live in wetland communities. Three important factors, however, contribute to the diversity of natural wetlands and form the basis for any wetland development protocol. These are hydrologic considerations, substrate, and vegetation. Assuming the above ingredients are correctly applied, scientists may either rely on natural colonization of the area with wetland plants or on artificial propagation techniques, such as seeding or transplanting. Through an understanding of the relationship between these factors, it is possible to determine which species should be planted, and by what means, under given environmental conditions. A more thorough discussion of these factors can be found in Department of the Army (1987), Lewis (1982), Allen and Klimas (1986), Allen, Pierce, and Van Wormer (1989), and Kusler and Kentula (1990).

When artificial propagation techniques are applied, seven forms of propagules are available for wetland vegetation establishment: seeds, rootstocks, rhizomes, tubers, cuttings, seedlings, and transplants. The most commonly used propagules for wetland establishment include all but seeds. Seed stands are typically difficult to establish because of unknown scarification and stratification requirements and loss of seeds via water action. Some successes have occurred with seeds of bottomland oaks and when wetland turf or agricultural grasses are used (1) on upper portions of basins that are never flooded or are not flooded until after seeds are established or (2) on saturated drawdown zones of reservoirs shortly after the water has been withdrawn. Wet prairie species also have been established in the tall grass prairie province by planting wild collected seeds with a seed drill.

SPRIGS AS A HERBACEOUS WETLAND ESTABLISHMENT TECHNIQUE: The most frequently used propagule for establishing marsh grasses and other herbs is sprigs. Often, sprigs are harvested from existing marsh stands and transferred to the target site. In other cases, seeds are germinated in the greenhouse to produce sprigs. An early study found that 44 *Spartina* seedlings germinated and tilled in the greenhouse generated 30,601 sprigs in about 10 months. The multiplication rate was 695 times. Tillering occurs when the seedling is placed in a soft growing medium, such as a mixture of vermiculite and sand, to allow the plant to produce shoots from the root or base of the stem. These shoots are continually dividing into more stems with roots. When these stems with roots are divided, they are called sprigs and can be transferred to the target site for planting or to transplanting beds or pots for later use.

SOILESS PROPAGATION TECHNIQUE: In Germany, Bestmann Ingenieurbiologie (bioengineering) has developed a system of propagating plants grown in a coconut fiber substrate without soil. Seedlings are produced in the greenhouse either from seed or vegetatively from tillering as described above. Plants are transferred as young seedlings to shallow-water flats outside the greenhouse containing the substrate and allowed to grow and spread (Figure 1). The substrate is treated with a fertilizer mixture to provide nutrients. After the substrate is filled with plants, the substrate and the pregrown plants are transferred to the target site and installed. This system offers several advantages:

- the substrate with pregrown plants and without soil is light and easily transportable;
- the substrate can be laid down as carpet (Figure 2), pallets (Figure 3), or individual bulblike containers (Figure 4), and is ready to grow with roots already established; and
- the pregrown plants in combination with the substrate produce a wetland system with high tensile strengths.

Figure 1. Plants transferred to shallow-water flats

Because of these advantages, such propagation methods lend themselves to areas where rapid and almost immediate wetland development is desired, such as in erosive environments along streambanks and lake shorelines.

This wetland system is good to use with low-cost building materials and structures for erosion control, such as stakes, posts, wire, and breakwaters. Such a combination of plants and building materials or structures is referred to as "bioengineering." Bestmann has used the above propagation approach using mostly freshwater herbaceous plants, such as various sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), and other forbs and grasses. Further information regarding this system can be obtained from the following source: Bestmann Green Systems, Attn: Ms. Wendi Goldsmith, P.O. Box 88, Boston, MA 02133, Phone 617-723-9404, Fax: 617-723-9430.

REFERENCES:

Allen, H. H., Klimas, C. V. 1986. Reservoir shoreline revegetation guidelines. Technical Report E-86-13. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Figure 2. The substrate laid as carpet

Figure 3. The substrate laid as pallets

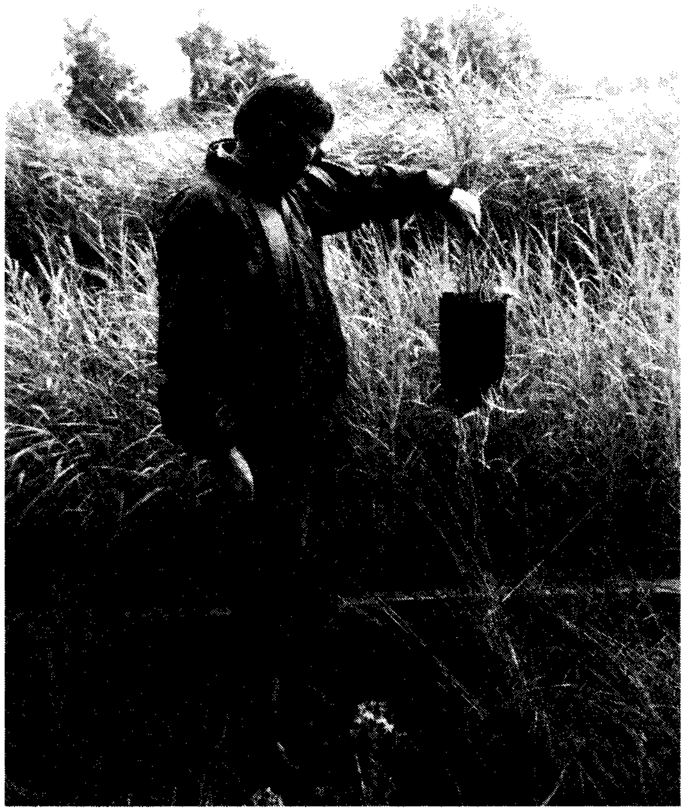

Figure 4. The substrate laid as individual bulblike containers

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WRP Technical Note VN-EM-3.2
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Basic Considerations for Vegetative Design of Wetlands

PURPOSE: This technical note addresses some conceptual or basic considerations for wetlands development or restoration with an emphasis on vegetation. A conceptual model is presented for this process.

BACKGROUND: Wetland development or restoration is often initiated without clear objectives of why the wetlands are being developed or restored other than to meet mitigation requirements. Little thought is given to the functions that wetland will perform and the economical and political requirements to develop or restore that wetland. More often than not, mitigation projects are implemented that do nothing more than plant some wetland vegetation so that legal restraints are satisfied and the project can proceed. Very little follow-up is done to check for plant establishment and that the wetlands are functioning as intended, if an intended function was indeed outlined at the beginning. Perhaps the problem is because, in part, there is not a conceptual model from which to plan the selection of wetland vegetation, planting techniques, handling, and aftercare that will, in part, determine the function or functions of the wetland. This technical note should be used as a conceptual design guide and in conjunction with a more specific design sequence presented in WRP Technical Note WG-RS-3.1.

MODEL COMPOSITION: This note draws largely upon similar thought processes presented by Leiser (1992) for use of vegetation and engineered structures for slope protection and erosion control. The processes are also similar for wetlands development and restoration and other areas of restoration ecology. The model involves the following stages:

Establishing objective(s)
⇓
Asking a series of questions/Developing answers to the questions
⇓
Development planning
⇓
Procuring plants, if necessary
⇓
Implementation, to include follow-up monitoring and management

- Establish objectives. Clear-cut objectives are needed to start any project, whether for wetlands development or restoration or any other project. The objectives may relate to developing wetlands to provide habitat, improve water quality, or a host of other desired functions. To meet these objectives, which are often driven by legal mandates, such as mitigation for dredging or filling wetlands, questions must be asked and answers provided before the project can proceed.

- Questions to be developed and answered. Any wetlands development/restoration project has several components or constraints. These components or constraints are interdependent and must be considered, thus generating an abundance of questions that should be answered, if possible.

They include the political, economic, climatatological, physical, edaphic (soils), and biological components of the project. All place constraints on the design of a project plan. Both the asking and answering of these questions relative to these components lead to the Plan of Development. Once the plan is well developed, procurement of plants may be required. After or concurrent with this procurement, implementation of the plan can proceed.

The political component includes governmental regulations, such as those presented in Section 404 of the The Clean Water Act (formerly known at the Federal Water Pollution Control Act, 33 U.S.C. 1344). It also includes public pressures, such as restricting wetlands development to the use of only native plant species or plants that are grown in a nursery as opposed to those borrowed or harvested from the wild. Governmental regulations and/or public pressures may also mandate that certain wetland functions be developed or restored. Lack of grazing controls, limitations on use of chemicals for rodent, insect, or weed control or fertilizers are other examples of these constraints and must be considered in any wetlands design criteria protocol. The political component also includes the negative human factors of vandalism and trespass by foot and off-road vehicles as well as the positive factor of public pressure for improvement of the environment.

The economic component is perhaps the most common limiting factor in wetlands development and restoration. This factor invariably affects the final decisions on the selection of plant species and planting densities, as well as pre-project experimentation and after-care activities. Often, construction and engineering of facilities take precedence and wetlands development or restoration for mitigation purposes is done with the concept of meeting legal requirements rather than what will work to obtain the desired functions of the wetland. A wetland design protocol must include funding for monitoring and allow for remedial planting and management of the site to meet the objectives of the project.

The climatatological component includes all of the aspects of the climate of a project site: rainfall (amount and distribution), temperature (heat and cold, time, duration, and intensity), humidity, day length, etc. Climatatological components affect wetland plant species selection, how those plants will be planted, and treatment after planting. With some exceptions, wetland projects in humid regions of the country with ample amounts of rainfall and along permanent-flowing streams will probably require less effort to develop than those along intermittent-flowing streams in dry climates. In desert climates, where fewer plants in the wetland inventory can be chosen than in humid climates, learning these plants' life requisites is essential for successful planting. The probability for wetlands development failure is higher with fewer species planted.

The physical component includes physical parameters of a project: site stability such as subsidence or accretion; aspect (compass bearing), which in turn influences environmental factors, such as temperature (south and southwest facing sites are hotter and evapotranspiration is higher than on other bearings); hydrodynamic aspects, such as water sources (groundwater, surface water), and water frequency, timing, depth, and duration; and energy sources such as wave and current action; and geomorphic features, such as landforms and terrain influences, such as the impacts of off-site water sources.

The edaphic component includes all the soil parameters: texture, structure, fertility, erodability, chemistry, etc. Soil texture, structure, and depth all affect the water-holding capacity of a soil and need to be considered when determining water retention requirements or supplemental irrigation requirements during dry periods of the year.

The biological component is one of the most important components and is interdependent with the other components. It includes habitat requirements of animal and plant species and can be modified to some extent to meet these requirements, if the life requisites of these species are known. This component also includes the availability of suitable plant species that, in part, make up the habitat for various wetland animals. Choices must be made between native and introduced species, obtaining plants from commercial nurseries, or from the wild. This component also includes the propagation and cultural practice for the plants, planting, and aftercare. It includes plant diseases, insects, predators, and the presence or absence of grazing animals. Protective screen sleeves or deer and grazing animal exclosures must be provided if these risks are present.

The potential for damage from insect, rodent, deer, and other predation must be considered and protection provided to planted wetland vegetation.

- Plan of development. Many of the questions regarding the above components can be answered off site, but a site analysis is mandatory before plants can be procured or before project implementation can occur. In the site analysis, each component must again be examined to include the various factors or parameters and what will influence wetland vegetation development or restoration. A general guideline for the site analysis, applies "Read" nature in the project area. From observations of a reference site, many answers can be found about what kinds of plants to use, invader species that are apt to occur, causes of problems, etc. The same or similar species that occur at the reference site should be procured. In a site analysis, much of the data from a reference wetland can be taken to answer the questions posed. Hydrological and soils data, for instance, may have to be procured, if they do not exist.

- Procurement of plants. Prior to the implementation of the project, procurement of plants must be made unless the project will use natural regeneration, e.g., reliance upon spread of existing plants, or spreading of mulch enriched with wetland plant seeds and propagules. To select vegetation for the project, vegetation existing on or near a site and on similar nearby areas which have revegetated naturally are the best indicators of the plant species to use. If commercial wetland plant sources are not available (USDA, Soil Conservation Service, 1992), then on- or off-site harvesting can be considered. When nourishing plants, care must be given to local or federal laws prohibiting such plant acquisition and decimating the natural stands of wetland plants must be avoided. Additionally, care must be taken to assure that pest species, such as purple loosestrife (*Lythrum salicaria*), are not collected and transferred to the project site.

  The availability of plants of the appropriate species, size, and quality is often a limiting factor in the final selection and plant procurement process. Some native plant species are very difficult to propagate and grow and many desirable species are not commonly available in commerce, or not available as good quality plants. As demand increases and nurserymen gain more experience in growing natives, this limitation should become less important (Leiser, 1992).

  Plant species composition and quantity can often be determined from the project objectives and wetland functions desired. As a general rule, it is advisable to specify as many species as possible and require the use of some minimum number of these species. Maximum and minimum numbers of any one species may be specified. Selection and acquisition of wetland plant species for wetland management projects is discussed more specifically in WRP Technical Note VN-EM-2.1.

- Implementation. This stage is the culmination of the conceptual and detailed design and includes site preparation and construction, planting, monitoring, and aftercare. For the vegetative design to be successful, this stage must have close supervision throughout by someone familiar with implementation of wetland development and restoration. This stage requires close attention to detail. Presently, there are relatively few people in the United States that have had the experience in doing this work well. Many contractors have done hydroseeding or sowing of grass cover for revegetation, but few have installed integrated projects including water control structures, biotechnical or bioengineering works, if required, and wetland woody and herbaceous plantings. It is important when initiating a wetland development or restoration project to consider who is available and capable of actually carrying out the project. This may include a team of persons with disciplines in such fields as engineering, soils, geology, hydrology, biology, and plant science. Regarding vegetation, the person should possess both training and experience in wetlands plant science and development. They should be willing to furnish credentials and references to that effect. It is mandatory that person be on site during project construction and especially planting.

All of the efforts to address the various components of design will be in vain unless plants are handled and cared for properly when planted and even after planting in many cases.

Equipment and materials. In the plan of development, consideration should be given to the equipment and materials required for vegetation handling and planting at the implementation stage. The tools required and the planting techniques will depend on the type of vegetation, i.e., woody or herbaceous, the size of plants, soils, and the size of the project and site conditions. Freshwater herbaceous plantings with low wave or current energy environments may call for tools like spades, shovels, and buckets. In contrast, high-energy environments of waves and currents may require tools for biotechnical installations. Such tools includes chain saws, lopping and hand pruners for the preparation of woody cuttings, and materials for woody biotechnical methods; or heavy hammers and sledges for driving stakes in biotechnical treatments such as wattling and brush matting. Specialized equipment may be required when moving sod or mulches containing wetland plants or plant propagules.

Other equipment and materials may include fertilizers, soil amendments, (i.e. lime), fencing for plant protection, and irrigation equipment for keeping plants alive during dry conditions. Other equipment and materials for keeping plants alive before they are planted may include shading materials such as tarps, buckets with water for holding plants, and hydraulic water pumps and hoses for watering or water trucks.

Planting techniques. There are several planting techniques for wetlands development or restoration ranging from simple digging with shovels or spades and inserting sprigs (rooted stems) or cuttings to moving large pieces of sod or mulch. Other methods consist of direct seeding or drilling individual seeds such as acorns of wetland oak species.

Monitoring. Most importantly monitoring and necessary aftercare must be a part of any wetlands design and must be included in the plan of development. The intensity and frequency of monitoring and aftercare will depend on site conditions, such as harshness of climate, probability of animal disturbance, high wave or current conditions, etc., and on established success criteria. The duration of vegetation monitoring will depend on the intended functions of the wetland. As an example, a wetland constructed for wastewater treatment may only require monitoring until the plants are well developed and assimilating waste materials; in contrast, a wetland developed for wildlife habitat may need to be monitored until it acquires the life requisites for particular target wildlife species. From monitoring, it may be determined that remedial efforts of additional planting or aftercare will have to be implemented.

On many sites, it is essential to protect wetland plantings from damage by animals, such as waterfowl, or beaver and other mammals. In a prior research program, geese were prevented from extirpating emergent aquatic plants planted along a Nebraska reservoir shore by erecting a temporary fence using wooden stakes and string. A row of stakes was placed lakeward of the wetland plantings and three courses of cotton string were attached to them. The waterfowl apparently do not like to land in what appears to be a narrow corridor that may hamper their escape. Fencing the entire site may be necessary where deer populations are heavy or where domestic animals graze.

The use of irrigation may be required during aftercare and will improve growth and survival of plantings that are installed during dry seasons and in dry soils such as sites occurring in bottomland hardwood systems. The decision about irrigation must be made based on economics contrasting the need to irrigate with the cost of possible mortality and the consequences of failing to obtain the desired wetland functions.

ADDITIONAL RECOMMENDED READING:

Gray, D. H., and Leiser, A. T. 1982. "Biotechnical Slope Protection and Erosion Control," Van Nostrand Reinhold Company, New York.

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CONCLUSIONS: The conceptual wetland design model presented allows appropriate planning for assuring success wetlands development or restoration.

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Baseline Site Assessments for Wetland Vegetation Establishment

PURPOSE: A critical stage in the successful establishment of vegetation for a wetland management project is plan development. The plan should include details on the influence baseline site conditions may have on wetland plant establishment and growth. Many sources are available that list information commonly acquired in baseline assessments, particularly regarding topography, hydrology, and soils (e.g., Kusler and Kentula 1990, Soil Conservation Service 1992, Hammer 1992). The following discussion is intended to help interpret how baseline site conditions will affect vegetation requirements necessary to meet project goals.

BACKGROUND: There are three basic components of wetlands affecting establishment and growth of desired vegetation: hydrology, soils, and existing vegetation. The site hydrology and soils create the physical site conditions. Existing vegetation is a reliable indicator of factors limiting on-site plant growth or may be a limiting factor itself. In addition, vegetation establishment is affected by land uses and off-site influences that can create adverse growing conditions. Potential adverse site conditions that limit plant growth include the following:

- unfavorable season and duration inundation
- unfavorable water depths
- wind and current action
- excessive turbidity
- unstable substrate
- steep slopes
- compaction and cementation of substrate
- extremes of surface temperature
- low nutrient status
- excessive stoniness and absence of fine, soil forming material
- broken, uneven surfaces
- sheet and gully erosion
- high levels of potentially toxic elements
- absence of soil micro-organisms and soil fauna

- presence of invasive or nuisance vegetation

- harmful levels of herbivory

In addition to identifying limiting conditions, the information gathered in a site assessment can be used to facilitate the wetland project plan development and implementation. For example, plant species growing on natural sites provide a good basic list of potential species for use in the project. These species are adapted to local conditions and are most likely to be successfully established and maintained. In addition, there are several methods by which plants existing on site can be used to vegetate the planned project. These include collecting the topsoil and redistributing it with the plant seeds and roots on the new site or cutting plugs from the existing wetland and moving it into the new wetland area. Both of these techniques require project scheduling to minimize storage time of the native material. Seeds and plant fragments (e.g., rhizomes and tubers) can be collected and grown in a greenhouse or nursery until needed for outplanting.

Determination of project success may be stipulated in some cases as a resemblance to a natural reference wetland. Assessment of wetland site conditions prior to project construction will aid in identification of a reference area. Furthermore, it may be required that physical and biological processes be monitored simultaneously in both the reference and project wetlands. Prior knowledge of project site conditions will aid in interpretations of monitoring results from the reference and project sites.

BASELINE SITE ASSESSMENTS:

- Project Topography. Plant establishment and growth requires stable substrates for anchoring root systems and preserving propagules such as seeds and plant fragments, and slope is a primary factor in determining substrate stability. Establishing plants directly on or below eroding slopes is not possible for most species. In such instances, plant species capable of rapid spread and anchoring soils should be selected or bioengineering techniques should be used to aid the establishment of a plant cover.

  Ground surface slope interacts with the site hydrology to determine water depths for specific areas within the site. Depth and duration of inundation are principal factors in the zonation of wetland plant species. A given change in water levels will expose a relatively small area on a steep slope in comparison with a much larger area exposed on a gradual or flat slope. Narrow planting zones will be delineated on steep slopes for species tolerant of specific hydrologic conditions, whereas gradual slopes enable the use of wider planting zones.

  In addition, soils on steep slopes generally drain more rapidly than those on gradual slopes. This means that soils remain saturated longer on gradual slopes with falling water levels, and roots remain in anoxic conditions even after aerial plant parts are exposed. If soils on gradual slopes are classified as poorly drained, care should be taken that plant species are selected for planting that are tolerant of saturation for longer periods of time than would be determined from surface water levels alone.

  Site topography affects maintenance of plant species diversity. Small irregularities in the ground surface (e.g., hummocks, depressions, logs, etc.) are common in natural systems. More species are found in wetlands with many micro-topographic features than in wetlands without such features. Raised sites are particularly important because they allow plants that would otherwise die while flooded to escape inundation.

A second topographic feature that promotes increased species diversity in littoral wetlands is a convoluted shoreline. Littoral drift along a straight shoreline carries seeds and plant fragments along with sediments, with little opportunity for the propagules to be captured and become established. Concave portions of shorelines trap sediments and propagules enabling more successful establishment and growth of more species.

- Hydrology. Wetlands vegetation is primarily limited by hydrology. Water limits diffusion of oxygen to buried seeds and root zones, which restricts germination and growth of most species. Wetland plants differ from terrestrial plants by having various morphological and physiological mechanisms that enable them to tolerate inundation of their roots; different species tolerate longer periods of inundation than others. Too much water, especially during the growing season, will stress plants and limit growth and establishment. Complete inundation of most plant species, even wetland species, can be lethal. Therefore, it is very important to be able to establish that the site will have enough water in the right place at the right time of year to support the plant species targeted for the project.

Hydrologic surveys of project sites should include estimates of water quantity and quality. It is desirable to plan hydrologic regimes with seasonal water level fluctuations similar to local natural wetlands. This enables the placement of local wetland plant species in hydrologic conditions similar to where they are naturally found growing. When water management requirements do not permit a natural analog as a planning guide for species selection and placement, more general planting guidance must be used, such as in the following water depth scheme for still, clear water.

PLANT GROWTH FORM	AVERAGE WATER DEPTH (cm)
Submergents (e.g., water celery, elodea, pondweeds)	>50
Floating leaves (e.g., water lily, spatterdock, lotus)	20-100
Herbaceous emergents (e.g., duck potato, bullrushes, maidencane)	0-50
Shrubs (e.g., buttonbush, wax myrtle)	0-20
Trees (e.g., cypress, green ash, red maple)	0-50

It should be noted, however, that young plants that are just developing from seeds or plant fragments do not have the same flood-tolerance as mature plants of the same species. Young plants are very susceptible to complete inundation, particularly during the growing season. Establishment success of herbaceous emergents, shrubs, and trees is often increased if water levels are managed the first one or two years to allow only short flooding periods and saturated substrates.

Water quality is a secondary factor that determines wetland plant distributions. Site evaluations of water quality usually include nutrients, pH, alkalinity, and turbidity, as well as salinity and toxins where appropriate. The water chemistry parameters are important for defining site-specific conditions for which tolerant plant species must be selected. Since most rooted plants acquire their nutrients from the soil, water chemistry is most important when considering submergent aquatic plants or potential eutrophication problems. Turbidity limits the depth of light penetration. Emergent plant species will grow in shallow turbid water; however, deep turbid water must be treated in order to support submerged aquatic vegetation.

- Soils. Several soil factors impact wetland vegetation. Assessment of site conditions for vegetation management must take into account whether the substrate will provide a stable rooting medium to an adequate depth for the target plant species. As described above, soil texture interacts with the hydrology and ground surface slope to determine the drainage capacities of the site that will affect the period of saturation. The soils must also provide adequate nutrients for plant growth and maintenance.

  Soil stability is dependent upon soil texture, surface slope, eroding forces such as wind and water, and vegetation cover. Vegetation management plans should utilize existing vegetation cover where practicable if stability is likely to be a problem. Target species may grow most successfully if planted through the existing plant cover that is stabilizing soils. Alternatively, competition from existing vegetation may require the use of control treatments. If this is necessary, it is advisable to use a treatment, such as mowing or herbicides approved for aquatic use, that leave the root systems intact to maintain stability until the target species become established. Establishment of a cover of rapidly growing annuals may be desirable to temporarily stabilize soils while the target plant species become established.

  Presence of a dense layer in the soil profile, such as rock, clay, or mineral deposits, needs to be closely examined because root penetration depths may be limited and drainage may be blocked. Root penetration depths differ with plant species. Generally, most fine roots that absorb nutrients occur in the top 30 cm of the soil. If an occluding layer is more than 30 cm deep, rooting depth is not usually a problem for herbs and shrubs. However, trees will require more rooting depth for increased stability against wind and currents. Limitation of drainage may be desirable to help maintain wetland conditions. If, however, an occluding layer is expected to create undesirable standing water conditions, either the layer needs to be broken up to allow drainage or plantings moved to more appropriate locations.

  There is little guidance available about what nutrient concentrations are desirable for wetland vegetation. Fertilizer application rates were developed for agricultural crops and do not necessarily apply to wetlands. Tolerance ranges of target plant species can be compared with soil analyses, particularly pH and cation exchange capacity (CEC). Nitrogen is the most common limiting nutrient for wetland plant growth because it is highly soluble and rapidly lost from the site through drainage and percolation. In addition, nitrogen is rapidly transformed into gases by microorganisms and is lost to the atmosphere before being utilized by plants. Surface application of nitrogen fertilizers in flooded conditions has proved to be less effective than subsurface applications and may lead to eutrophication problems. By applying a slow-release fertilizer in the planting hole with the plant, it is directly accessible to the roots and the rates of nutrient loss to the atmosphere and water column are reduced.

- Vegetation. A primary objective for characterizing vegetation on site is to determine whether or not plantings will be required. Species dominance and/or quantities should be determined for all strata (i.e., canopy, shrub, and herbaceous) on the project site. The environmental tolerances of the naturally occurring species can then be compared with the projected conditions of the managed wetland. If species are not present in adequate amounts that meet project goals and that will tolerate the managed site conditions, appropriate plant species will have to be acquired and planted.

Maps of existing vegetation associations can be helpful in assessing management options. The plants themselves are good indicators of environmental conditions such as frequency and duration of inundation or soil conditions, and project plans can be optimized by "reading" the plant distributions. It should be recognized that different growth forms of plants indicate site conditions over different periods of time. Tree life spans are longer than herbs, and the conditions under which mature trees were established may have changed over time, whereas short-lived herbs are more likely to reflect recent conditions. Therefore, disparities between environmental tolerance ranges between herbs and canopy strata indicate that a change has occurred in site conditions. For example, a herb layer dominated by mesic species can be located under a facultative-wet tree overstory. Impacts to unique or sensitive vegetation should be avoided, particularly if alternate areas are available for project development.

Baseline site assessments will help determine whether or not site preparation is necessary and define which site preparation methods will be most appropriate to meet project goals. Site preparation methods can utilize the existing vegetation to maintain site stability until a managed suite of species becomes established. For example, a project objective may be the maintenance of cover by existing herbaceous species while planted trees mature, but competition must be reduced for adequate tree growth. Strips can be disked where trees will be planted while maintaining the value of existing vegetation as the target trees grow.

Site preparation for wetland vegetation management may require that site conditions be ameliorated, particularly if the site has been damaged (i.e., substrate instability, nutrient losses, or high toxin concentrations) or neglected. Poor site conditions can be accepted as they are (e.g., absence of topsoil, erosion, unstable substrate, etc.), and species can be planted that are tolerant of these conditions, such as early colonizing or "pioneer" species that are often annuals. Attempts can be made to incorporate soil amendments into the substrate (e.g., organic matter, lime, or fertilizer). Material brought to a site can be brought from a donor site with similar characteristics to the desired managed wetland. Plant seeds and propagules in this material will help to rapidly develop a species rich ground cover.

- Wildlife Survey. Animals affect vegetation in several ways. Plants can be stimulated to grow with fertilization or limited browsing. However, animals can eradicate plants that are too heavily browsed or that cannot grow in soil compacted by trampling. Plant species diversity can be decreased if browsers favor some species and leave unpalatable species. Seeds of volunteer species can be brought on site by animals.

  Control measures can be planned to limit access of animals to a project area if the baseline assessment indicates there may be problems. For example, fences can be erected to keep large animals, such as deer, off the site. Some animals, like beaver and nutria, can be periodically trapped and removed. Insect infestations should be treated on an as-needed basis. If practicable, it is preferable to limit access of nuisance fish species to aquatic sites with net or fence enclosures than to kill and remove all fish in an area.

CONCLUSION: Baseline site assessments should include historical, physical, chemical, and biological information that must be considered for successful establishment and management of wetland vegetation. A basic familiarity with how pre-project site conditions will affect plant growth can be used to improve project plans and the chances of attaining project goals.

ADDITIONAL SOURCES OF INFORMATION: For more details about baseline site assessments consult the following references:

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Species Match Ensures Conversion of Wet Agricultural Fields to Bottomland Hardwood (BLH) Wetlands

PURPOSE: This technical note provides guidance for determining species composition when planning the reforestation of BLH wetland restoration sites.

BACKGROUND: BLH wetlands are recognized to perform wildlife, water quality, and recreation functions. Significant losses in acreage and the concomitant loss of functions have occurred primarily because of clearing and drainage for agriculture. Implementation of the 1985 Food Security Act has slowed the loss of BLH acreage, and federal programs such as the Wetlands Reserve Program have promoted the restoration of flood-prone agricultural land to BLH wetlands. Also, these wet fields provide an excellent option for the mitigation of impacts required by the Clean Water Act amendments.

During the planning of a BLH wetland restoration project, observing the regional natural interrelationship between hydrology, soils, and vegetation can serve as a useful guide toward selecting the desirable tree species and matching them to particular locations. However, agricultural land suitable for BLH wetland restoration may still have significant alterations in hydrology and soil physical properties. Soil grading and levees may have decreased or increased the depth and duration of flooding. A plow-pan may have formed, increasing the duration of soil saturation or flooding. Drainage channels could decrease the frequency, depth, and duration flooding in one area but, because of the enhanced water conveyance, could increase the frequency, depth, and duration of flooding in another area.

Consideration must also be given to changes in hydrology upstream or downstream within the watershed which can significantly influence onsite hydrology (for example, discharge from a reservoir upstream from the restoration site). Consequently, decisions regarding the location of various species may be more difficult. Familiarization with the location and type of hydrologic alterations may enhance the reforestation planner's options in locating desirable tree species. For example, cherrybark oak (*Ouercus pagoda* Raf.) is arguably the most desired bottomland hardwood species because of its wildlife and timber value. Areas where flooding and soil saturation have been reduced by drainage channels or levees may now support this weakly flood-tolerant species.

Knowledge of both the site characteristics and the ecological characteristics of the endemic BLH tree species is necessary when trying to successfully match species to a BLH wetland restoration site.

METHODS: Obtaining a thorough knowledge of the restoration site and the endemic tree species will require both office and field work.

OFFICE WORK: Of the three parameters that define a wetland (wetland hydrology, hydric soils, and hydrophytic vegetation), hydrology is the least understood and measured factor. A United States Geological Survey (USGS) 7.5-min quadrangle map will provide an idea of topography, water bodies and drainage patterns within the site. Also, acquiring quadrangle maps depicting lands adjacent to the restoration site may provide an idea of upstream and downstream hydrologic influences. Remember that the contours are usually mapped at only 10-ft (3-m) intervals. This is probably insufficient for making decisions on the location of microsite concave landforms (hollows, swales, etc.) which could on occasion exhibit flooding or soil saturation conditions. Ridge and swale topography where the relief is less than a few feet can have significant influences on the overall site hydrologic characteristics (for example, the Mississippi Delta). If the site is located near a large stream or river, the USGS or Corps of Engineers (CE) may have stream gauge data available. Combining gauge data with the topographic maps can provide an idea of the frequency, duration, timing, and location of flood events.

Aerial photographs can provide direct evidence for the time and location of flooding or soil saturation. The U.S. Agricultural Stabilization and Conservation Service (ASCS) photographs agricultural land yearly in order to monitor the compliance of federal programs, and may be a good source for aerial photos. The CE, the U.S. Fish and Wildlife Service, or private companies may also be a good source for aerial photography.

Topographic maps, stream gauge data, and aerial photos can provide information on surface water hydrology but provide little information on potential groundwater influences. Flooding or soil saturation within the root zone (within 20 in. (50 cm) of soil surface) caused by groundwater will influence tree species distribution in a similar fashion as surface water hydrology. Unfortunately, time will probably not permit a surficial groundwater monitoring effort using piezometers, and published data for the particular restoration site are probably not available. However, contacting the USGS, CE, or a local university may be helpful in acquiring any available information on groundwater.

Information on soils can best be obtained from a U.S. Soil Conservation Service (SCS) County Soil Survey. If available, a survey usually can be obtained from the SCS county field office. If copies are unavailable or the site has not been soil mapped, the SCS county field office will probably have information on the soil conditions.

A basic understanding of the regional ecology is recommended. Knowing how the local environment influences plant distribution and successional patterns can give the reforestation planner a mental picture of how newly created forest will progress over time. If restoring wildlife habitat is an objective, a better perception may be gained of animal habitat needs and animal use patterns. Published literature on the local ecology can sometimes be found in the "Local Interest" section of private bookstores. City, county, or university libraries may also be a good source for regional ecology literature. Do not hesitate to contact faculty members within the biology, botany, forestry, or agriculture departments at local colleges and universities. They may be of immense help in locating literature or answering direct questions regarding topics relative to the restoration project.

FIELD WORK: Ideally, completing all background data collection and review prior to a site visit will better organize the restoration planner's time in the field. This is especially important when the restoration project encompasses a large area. More valuable field time can be spent in problem areas indicated by the office review. In addition to all maps, aerial photos, and soils information, plan to take a small notebook, camera, and spade. Use the notebook to map special features or problem areas and to write general comments. Nothing you see or think about regarding the restoration effort should be considered frivolous. The camera will be used to photograph the general appearance of the landscape and potential problem areas. The spade will be used to verify published soils information by digging small soil pits for determination of soil texture, structure, and color. Dig the soil pits deep enough to include the root zone (at least 20 in. (50 cm) deep) in order to observe any growth obstructions such as a plow-pan or high water table. The notes and observations made should be readily transferable to a reforestation plan map. The map will include the field observations as well as the location of tree species to be planted.

It is strongly recommended that the site visit occur when the hydrologic influences are the greatest. For example, in the Mississippi Delta, potential BLH wetland restoration sites should be visited during the winter and early spring when flooding and soil saturation conditions are usually the most severe. Summertime visits would probably provide little evidence of the location, depth, and duration of flood events. If this is not possible, observing soil color can be of special significance with regard to presence of anaerobic conditions caused by flooding or soil saturation. If, within the root zone, the soil color is gleyed or the matrix chroma is low with or without bright mottles, the area may experience long-term flooding or soil-saturated conditions. Remember that the soil color indicator may represent a condition previous to the clearing and drainage for agriculture.

When walking the site, consider the potential animal impacts that may affect seedling survival and growth. The agricultural field looks like a wildlife wasteland now but, after tree planting, may quickly be colonized by animals such as beavers, nutria, feral hogs, rabbits, and deer. Beavers may dam drainage channels, inundating areas that had been determined as relatively dry. Always remember that even seedlings of flood-tolerant tree species will be adversely affected by long-term flooding or soil saturation.

Do not hesitate to establish a friendly relationship with the local residents. Ask the current farmer or adjacent landowners about flooding hot spots or soil problems on the site. These people may be your best source of information about groundwater influences, since many of them have recently drilled water wells on their property. Ask the farmer about the pesticides and mineral fertilizers used to grow the crops in the target and adjacent fields. Aerial applications of pesticides are used for many of the agricultural fields in the Mississippi Delta. Be aware that herbicide drift from adjacent agricultural fields may adversely affect seedling survival and growth. Unfortunately, there are probably few options to prevent this damage. One would be to convince the adjacent farmers to switch to a ground-based application system. A friendly relationship with the local residents could lead to a wealth of information about the site. Also, they may be more willing to help a familiar face in case of an emergency.

Field work should include selecting a BLH wetland reference site near the restoration site. With the high loss of BLH wetlands, this may be easier said than done. As best as possible, choose a reference site with similar soils, topography, and hydrology as the restoration site. In the Mississippi Delta, a common soil series association is the Dundee, Forestdale, and Sharkey catena. It would not be uncommon for the restoration site and a nearby forested site to be represented by this catena. During your walk-through, note the tree species located on each soil type. Consult the literature for the flood tolerance of the species observed (Table 1). The list created will be a good starting point in determining the desired tree species to plant and their location within the restoration site.

Because the wet agricultural fields usually have extensive alterations in hydrology, a temptation exists to plant tree species in locations where they would not be found in undisturbed conditions. A research study conducted at the Corp's Lake George Bottomland Hardwood Wildlife/Wetland Restoration Site, Mississippi, suggests that the natural tree species and soils relationships exist, despite the significant flood prevention activity on the site. The study consisted of planting Nuttall oak (*Ouercus nuttallii*, Palmer), water oak (*Ouercus nigra*, L.) and cherrybark oak seedlings on a Dundee, Forestdale, and Sharkey soil series. Nuttall oak, water oak, and cherrybark oak are moderately flood tolerant, weakly flood tolerant, and flood intolerant, respectively. The Forestdale and Sharkey soil series are hydric soils prone to long-term flooding or soil saturation, while the Dundee soil is a nonhydric soil. The hydrology on the study site is influenced by several large drainage channels. Nuttall oak had high first-year survival on all three soil series (Table 2). Water oak had lower survival than the Nuttall oak, but it was comparable on all three soil types. The flood-intolerant cherrybark oak performed poorly on the hydric

Table 1
Relative Flood Tolerance of Selected Bottomland Hardwood Tree Species Planted on Restoration Sites[1]

Common Name	Scientific Name	Flood Tolerance[2]
Green ash	*Fraxinus pennsylvanica*	Moderate
River birch	*Betula nigra*	Moderate
Eastern cottonwood	*Populus deltoides*	Moderate to weak
Baldcypress	*Taxodium distichum*	Tolerant
Water elm	*Planera aquatica*	Tolerant
Sweetgum	*Liquidambar styraciflua*	Moderate
Black tupelo	*Nyssa sylvatica* var. *sylvatica*	Weak
Swamp tupelo	*Nyssa sylvatica* var. *biflora*	Tolerant
Water tupelo	*Nyssa aquatica*	Tolerant
Sugarberry	*Celtis laevigata*	Moderate
Water hickory	*Carya aquatica*	Moderate
Shellbark hickory	*Carya laciniosa*	Weak
Red maple	*Acer rubrum*	Moderate
Cheerybark oak	*Quercus pagoda*	Weak to intolerant
Laurel oak	*Quercus laurifolia*	Moderate to weak
Live oak	*Quercus virginiana*	Weak to intolerant
Nuttall oak	*Quercus nuttallii*	Moderate
Overcup oak	*Quercus lyrata*	Moderate
Pin oak	*Quercus palustris*	Moderate
Shumard oak	*Quercus shumardii*	Weak
Swamp chestnut oak	*Quercus michauxii*	Weak
Water oak	*Quercus nigra*	Weak to moderate
Willow oak	*Quercus phellos*	Weak to moderate
Persimmon	*Diospyros virginiana*	Moderate
American sycamore	*Platanus occidentalis*	Moderate
Black willow	*Salix nigra*	Tolerant
Yellow-poplar	*Liriodendron tulipifera*	Intolerant

[1] Adapted from McKnight and others (1981).
[2] Tolerant = Species able to survive and grow on sites in which soil is saturated or flooded for long, indefinite periods during the growing season.
Moderate = Species able to survive and grow on sites in which soil is saturated or flooded for several months during the growing season, but high mortality can be expected if flooding persists or reoccurs consecutively for several years.
Weak = Species able to survive and grow on sites in which soil is saturated or flooded for relatively short periods during the growing season.
Intolerant = Species that are not able to survive even short periods of soil saturation or flooding.

Table 2
First-Year Survival by Species and Soil Series for the Lake George, MS, Study

Tree Species	First-Year Survival (Dundee Forestdale Sharkey), percent		
Cherrybark oak	91	53	50
Water oak	65	57	71
Nuttall oak	99	97	94

soils despite the potential for enhanced drainage by the drainage channels. The ponding or soil saturation caused by rainfall in the slowly permeable Sharkey and Forestdale soils may be sufficient to create anaerobic conditions detrimental to the root systems of cherrybark and water oak.

CONCLUSIONS: Other questions regarding the BLH wetland reforestation effort that remain to be answered include species availability, planting stock type, planting schedules, delivery and storage concerns, and planting methods. Literature is available to help in the overall planning of a BLH wetland restoration project (Allen and Kennedy 1989, Kusler and Kentula 1990, Hammer 1992, Allen 1993, Davis 1993).

A thorough knowledge of the BLH wetland restoration site and the flood tolerance of the endemic tree species will aid in successfully matching the right species to a particular location.

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